LATERAL VARIATIONS IN CONODONT SPECIES RELATIVE ABUNDANCE IN CINCINNATIAN ROCKS OF NORTHERN KENTUCKY

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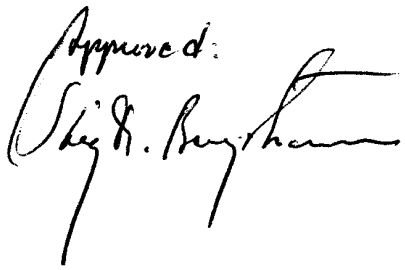

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Introduction

For some years, variation in the relative abundance of representatives of certain conodont species has been used as an aid in regional biostratigraphic correlations of late Middle and Upper Ordovician rocks in the North American Midcontinent (Sweet and others 1965; Bergström and Sweet 1966; Sweet and Bergström 1971, etc.). Correlation by means of this "relative abundance analysis" (Sweet and others 1965) has been based on the assumption that relative abundance changes for a particular species were contemporaneous over the study area and caused by parameters that affected the conodont populations in a similar way basin-wide.

Although correlations based on this principle have proved to yield results that are compatible with other lines of evidence, thus far no study has been carried out on the relative frequency changes of conodont species in a very thin stratigraphic interval over a limited area as a test of the assumption mentioned above. The Cincinnatian rocks in Kentucky and Ohio offer excellent opportunities for such a study because of the fact that in many exposures of those strata, thin but persistent limestone beds can be followed over considerable distances, Furthermore, these rocks are known to contain abundant conodonts and the vertical range and taxonomy of individual species are well known.

The purpose of the present project was to study the lateral variation in the relative abundance of selected conodont species in Cincinnatian rocks in a number of sections in Fleming, Mason, and Robertson Counties, Kentucky. In order to achieve this goal, several laterally spaced samples of selected lime-

stone beds were collected at a number of road cuts along U.S. Route 68. These samples were subsequently analyzed for conodonts. Because these sections had not been dated previously by conodonts or other fossils, a second goal of this investigation was to evaluate the age of the rock succession exposed at each of the sections as precisely as possible on the basis of the collected conodonts.

Acknowledgments

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Methods

Cincinnatian rocks are excellently exposed in numerous road cuts along U.S. Route 68 in northern Kentucky. Some of these sections are hundreds of yards long and individual limestone beds can be followed, in many cases, along the entire extent of these cuts. For the present investigation, exposures of the Kope and Fairview Formations of early Cincinnatian age were studied and sampled because they were found to provide suitably persistent limestone beds in addition to being the largest cuts found. The individual beds sampled were chosen among those that could be traced laterally for the longest distance; such beds have generally a thickness of a foot or more whereas thinner beds could not be traced very far before they pinched out or became indistinct.

Five rock samples were collected at horizontal intervals of 36 to 176 feet from a particular bed along each section, and the present investigation includes a total of twenty-five samples. All samples were taken from the

lowermost one to two inches of each bed sampled and great care was exercised in collecting, as closely as possible, precisely the same part of an individual bed.

The rock samples were subsequently crushed to gravel in a rock crushing machine in the laboratory. The crushed rocks were washed, and 1000 gram samples were dissolved in a 15 percent solution of acetic acid. With one exception, the samples proved easy to digest and the undissolved residue was screened and that part between 20 and 100 mesh was saved. This residue was later dried in an oven and subsequently put through a Franz Isodynamic Separator. The non-magnetic fraction of the residue was searched for conodonts under a binocular microscope. The conodont elements were picked out and mounted on micro-paleontological slides, one slide for each rock sample. The identification of individual elements was carried out, using papers by Bergström and Sweet (1966), Pulse and Sweet (1960), and Kohut and Sweet (1968).

Descriptions of Sections

Blue Licks State Park Section

The Blue Licks State Park Section is located in Robertson County, Kentucky and is a road cut on the west side of U.S. Route 68 immediately east of Blue Licks Battlefield State Park (Fig. 1). Rocks exposed in this section were classified as the Kope Formation because they include predominantly shale with thin limestone beds — the typical Kope lithology — and because they occur at an altitude of about 710 to 740 feet above sea level, which is within the range of the altitude of the Kope Formation in this area. The conodonts found suggest an Edenian age for the strata investigated; the Kope Formation has been dated as largely of Edenian age in nearby areas of Kentucky (see, for instance, Sweet and Bergström 1971).

The units recognized in this section are as follows from top to bottom (see Fig. 2 for columnar section):

	feet	inches
Unit A. Shale with limestone lenses and limestone nodules. Limestone gray, thin-bedded, not very fossiliferous.....	4	2
Unit B. Limestone, gray, weathering yellow, fossiliferous. A very persistent bed.....	1	1
Unit C. Shale, gray, unfossiliferous.....	0	7
Unit D. Limestone, gray, coarse-crystalline. The samples collected for conodonts were taken from the lower 1-2 inches of this bed.....	1	1
Unit E. Shale with lenses of limestone. Limestone gray, thin-bedded.....	3	1
Unit F. Limestone, gray, in two distinct beds.....	1	6
Unit G. Shale with a few limestone lenses. Limestone gray, thin-bedded, not very fossiliferous.....	3	0
Unit H. Limestone, gray, with numerous brachiopods. A very persistent bed.....	0	9
Unit I. Shale with limestone lenses, Limestone gray, fine-grained.....	1	3
Unit J. Limestone, gray, fossiliferous, coarse-grained, in three beds.....	1	10
Unit K. Limestone and shale, interbedded, about 50% of each.....	0	11
Unit L. Limestone, gray, fossiliferous.....	0	5
Unit M. Shale with lenses and impersistent beds of limestone. This is the lowermost unit exposed in the cut.....	3	1
Total thickness of measured section	22 feet, 9 inches	

There are at least 20 feet of additional section above the measured section in this cut.

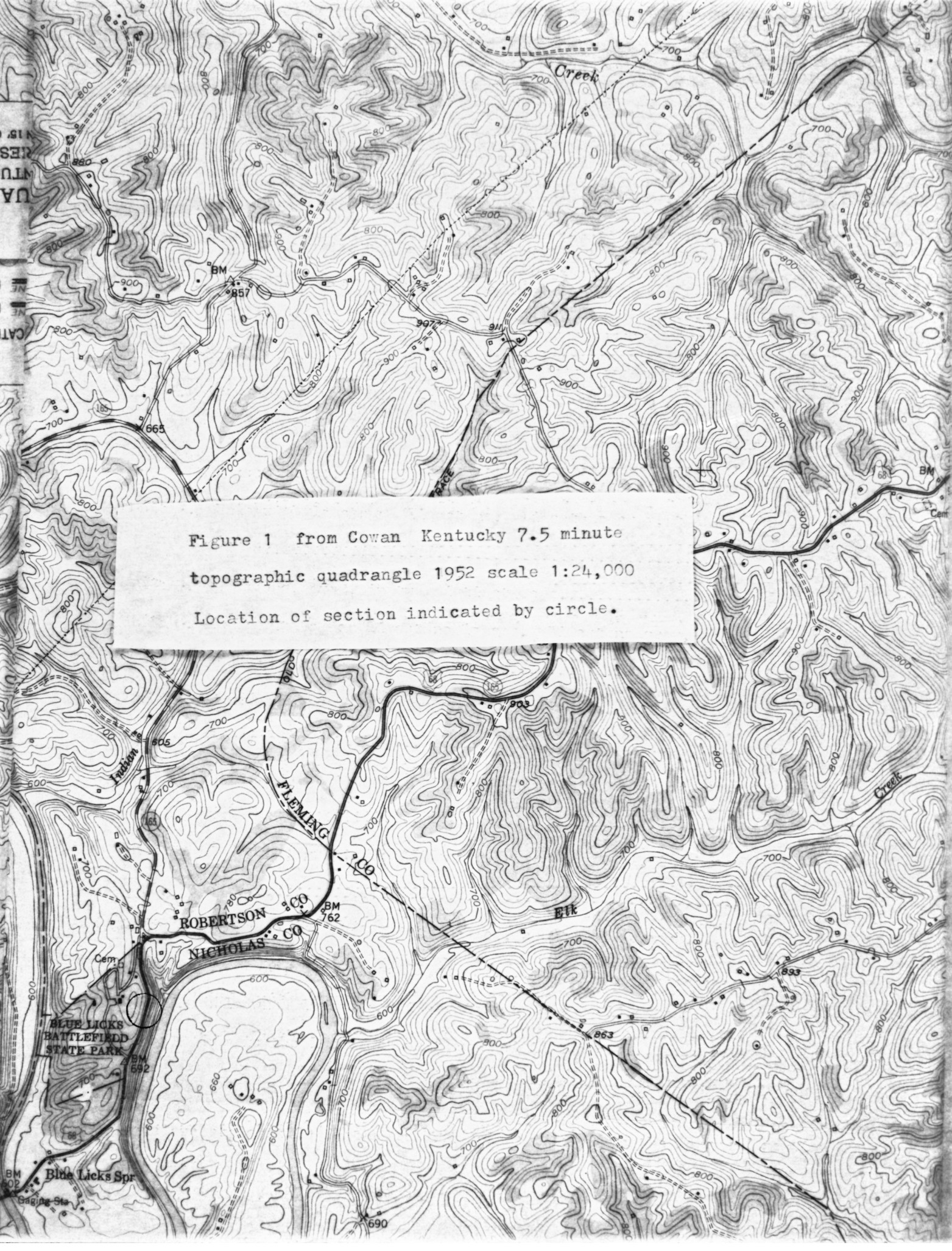
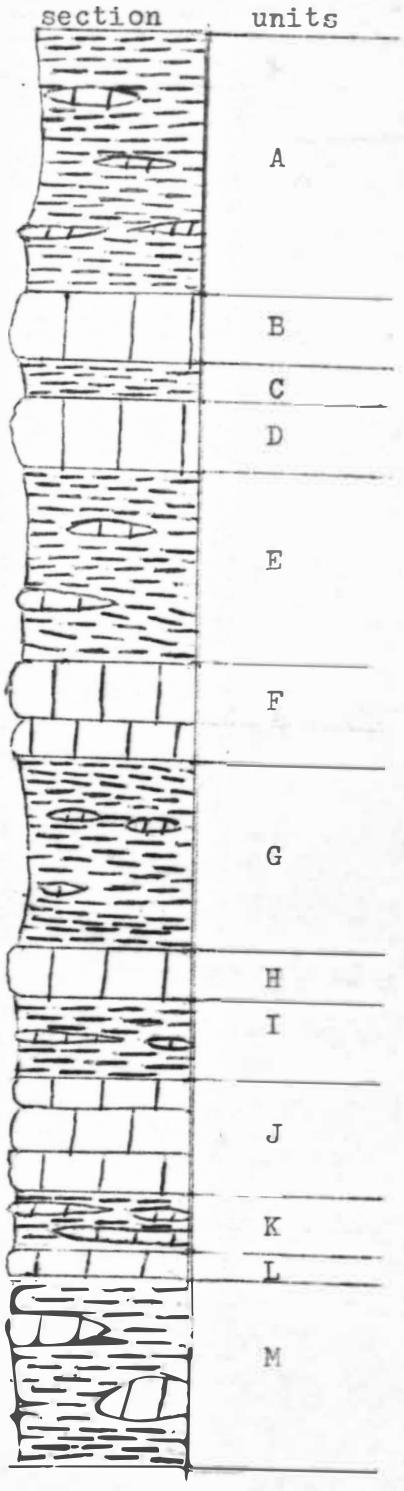


Figure 1 from Cowan Kentucky 7.5 minute topographic quadrangle 1952 scale 1:24,000 Location of section indicated by circle.

Figure 2

Scale: 1:30

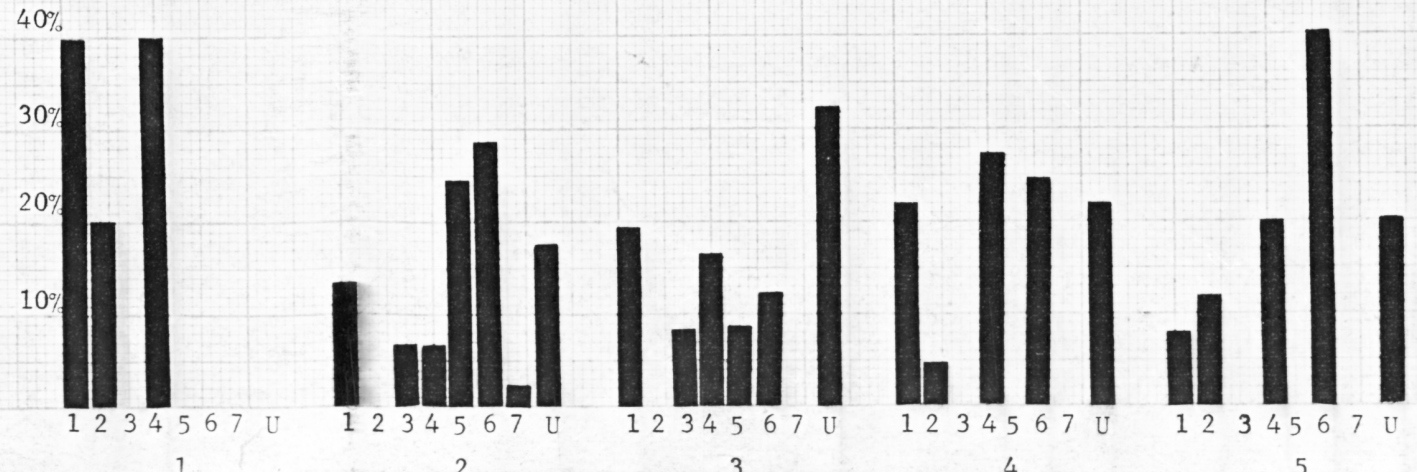
Blue Lick State Park section



Kope Formation

Blue Licks State Park Figure 3

Species	number in each sample				
	1	2	3	4	5
1. Drepanodus suberectus	2	6	11	9	2
2. Ozarkodina tenuis	1			2	3
3. Ozarkodina obliqua		3	5		
4. Plectodina furcata	2	3	9	11	5
5. Oulodus oregonia		11	5		
6. Phragmodus undatus		13	8	10	10
7. Bellodina compressa		1			
U. Unidentified		8	18	9	5
Total	5	45	56	41	25



Sample 10-1 was collected from Unit D at the western end of the exposure, and other samples of the same bed were collected going eastward from this point. The distance between successive samples is as follows:

From 10-1 to 10-2 ..... 120 feet
10-2 to 10-3 ..... 114 feet
10-3 to 10-4 ..... 120 feet
10-4 to 10-5 ..... 176 feet

A list of species found in these samples and their relative frequency are given in Fig. 3.

Fairview Section

The section referred to as the Fairview Section is a road cut on the northwest side of U.S. Route 68 in Fleming County, Kentucky about a mile west of Mason County line (Fig. 4). At a vertical distance of 13.5 feet above the base of the third bench in this very high section is a distinctive change in lithology from predominantly shale below to limestone above. This level is taken to be the boundary between the Kope and Fairview Formations. The boundary is at an altitude of 820 feet. The conodonts were collected from strata identified as the Kope Formation and the conodont fauna is of Edenian age. As noted above, the Kope is largely of Edenian age in this part of Kentucky.

The lithologic units recognized in this section below the base of the Fairview Formation are as follows (see Fig. 5 for columnar section):

	feet	inches
Unit A. Shale with some limestone beds; these gray, thin-bedded. This is the uppermost unit beneath the Fairview Formation.....	3	6
Unit B. Limestone, gray, fossiliferous. Samples 14-1 through 14-5 were collected from the lower 1-2 inches of this bed.....	0	9
Unit C. Shale with numerous limestone beds, 1-2.5" thick.....	4	1

	feet	inches
Unit D. Covered interval to the base of the third bench.....	5	2
Unit E. Limestone, gray, forming top of bench.....	1	1
Unit F. Shale with some lenses of gray limestone.....	1	6
Unit G. Limestone, gray, fossiliferous. A prominent bed.....	0	11
Unit H. Shale, gray and limestone. Shale/limestone ratio 75%/25%.....	4	3
Unit I. Limestone, gray, fossiliferous, persistent bed.....	1	1
Unit J. Shale with limestone lenses.....	0	11
Unit K. Limestone, gray, fine-grained, persistent bed.....	0	6
Unit L. Shale, gray.....	1	10
Unit M. Limestone with some shale. Limestone gray, in beds mostly about 1 inch thick.....	5	9
Unit N. Limestone, gray, fossiliferous, forming persistent bed.....	0	6
Unit O. Shale with limestone nodules.....	1	0
Unit P. Limestone (predominantly), gray, in 1-2" thick beds.....	3	11
Unit Q. Covered interval to base of second bench.....	3	11
Unit R. Limestone, gray, very fossiliferous.....	0	8
Unit S. Shale, gray.....	0	11
Unit T. Shale, gray, with limestone lenses.....	4	4
Unit U. Limestone with some shale; limestone beds up to 4" thick	3	5
Unit V. Shale with a few limestone beds.....	3	8
Unit W. Limestone, gray, fine-grained, argillaceous; and shale, gray, calcareous. Limestone/shale ratio 50%/50%. Limestone beds less than 2" thick.....	5	0
Unit X. Shale (predominantly); gray, thin-bedded limestone, in beds 1-3" thick; limestone fine-grained, argillaceous...	5	2

	feet	inches
Unit Y. Limestone, gray, fossiliferous, very persistent bed, Samples 11-1 through 11-5 taken from lower 2" of this bed.....	0	7
Unit Z. Shale with some limestone lenses.....	4	10
Unit AA. Covered interval to base of first bench.....	5	2
Total thickness of measured section	74 feet, 5 inches	

Beneath the first bench, there is at least 25 feet of Kope Formation that was not measured.

The samples in series 11 were taken from Unit Y; the first sample was collected from the southwestern end of the cut, and the other samples from the same bed going northeast. The distance between successive samples is as follows:

From 11-1 to 11-2 ..... 90 feet
11-2 to 11-3 ..... 66 feet
11-3 to 11-4 .....102 feet
11-4 to 11-5 ..... 90 feet

The samples in series 14 were taken from Unit B. Sample 14-1 was collected from a point 66 feet from the southwestern end of the cut and other samples northeast of this point. The distance between successive samples is as follows:

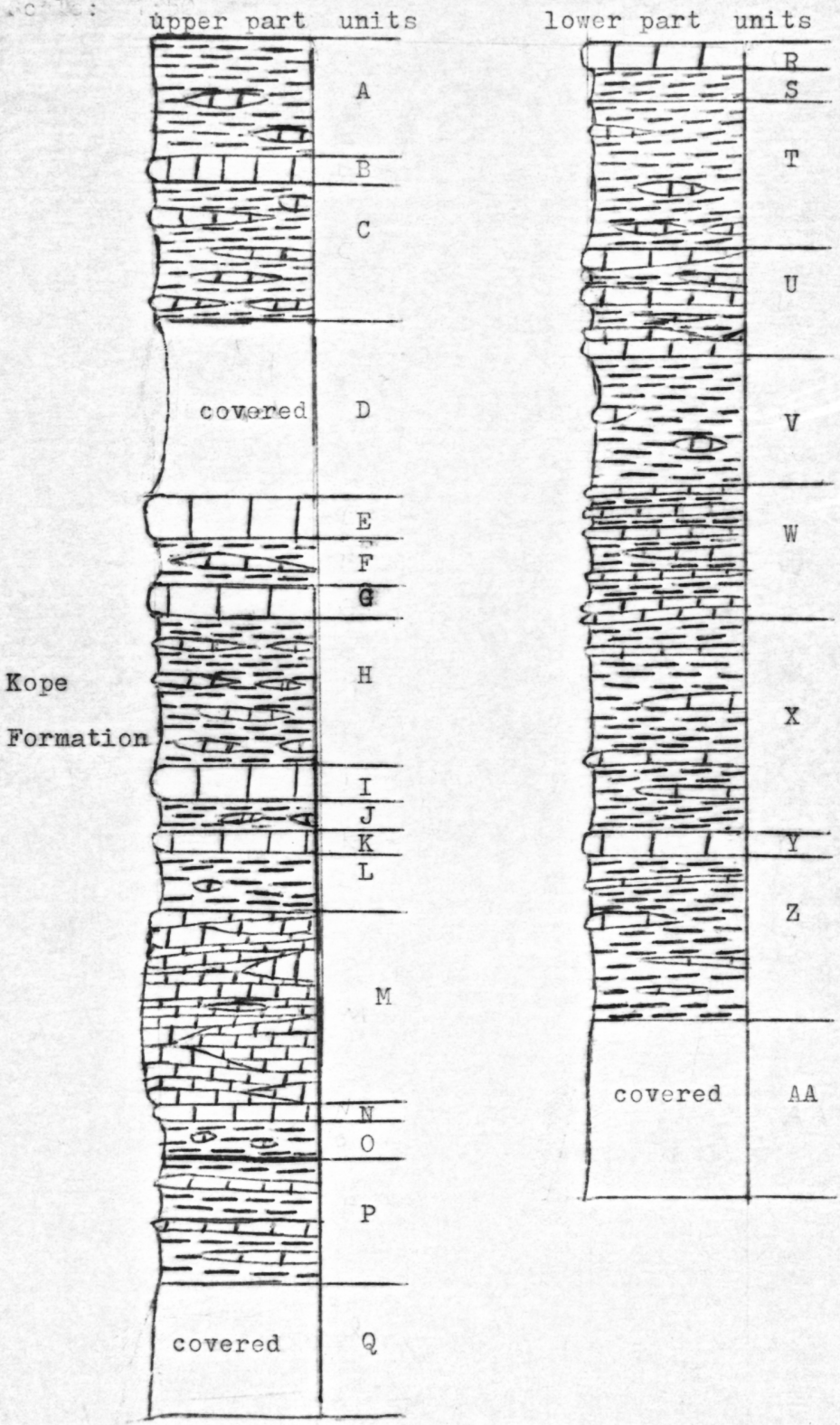
From 14-1 to 14-2 ..... 55 feet
14-2 to 14-3 ..... 56 feet
14-3 to 14-4 ..... 66 feet
14-4 to 14-5 ..... 78 feet

A list of species found in these samples and the relative frequency of these species are given in Figs. 6 and 7.

Figure 4 from Cowan Kentucky 7.5 minute topographic quadrangle 1952 scale 1:24,000 Locations of sections indicated by circles.

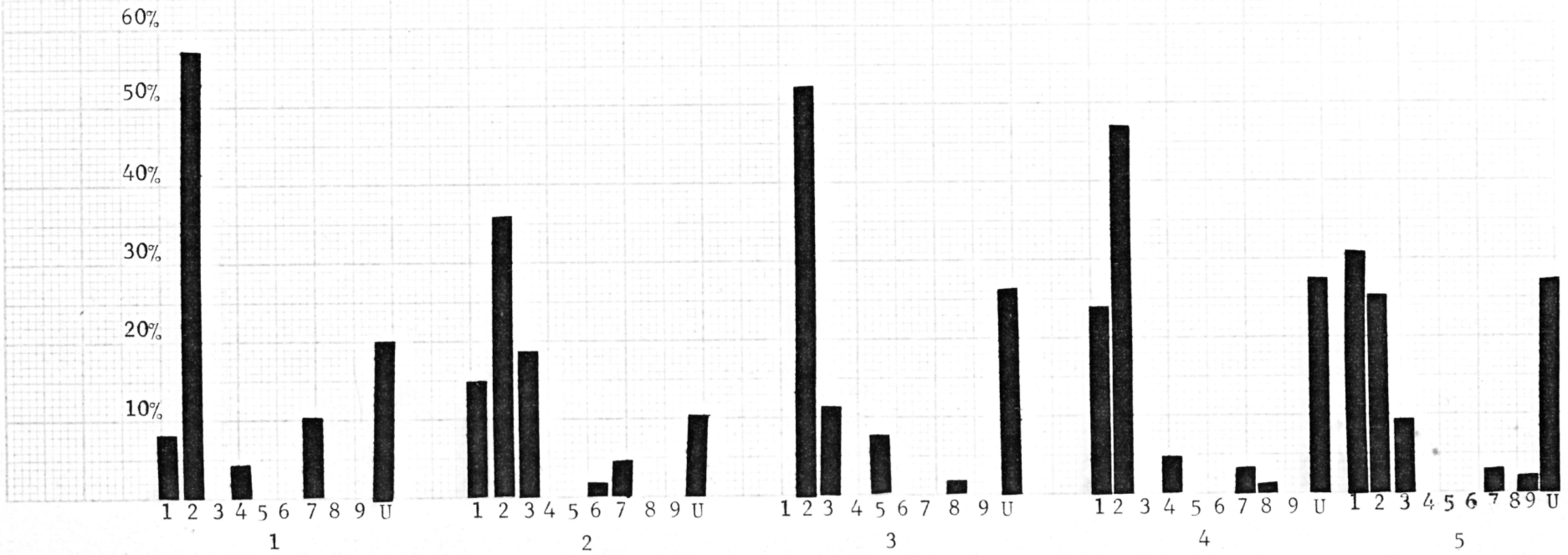
Figure 5 Scale: 1:50

Fairview



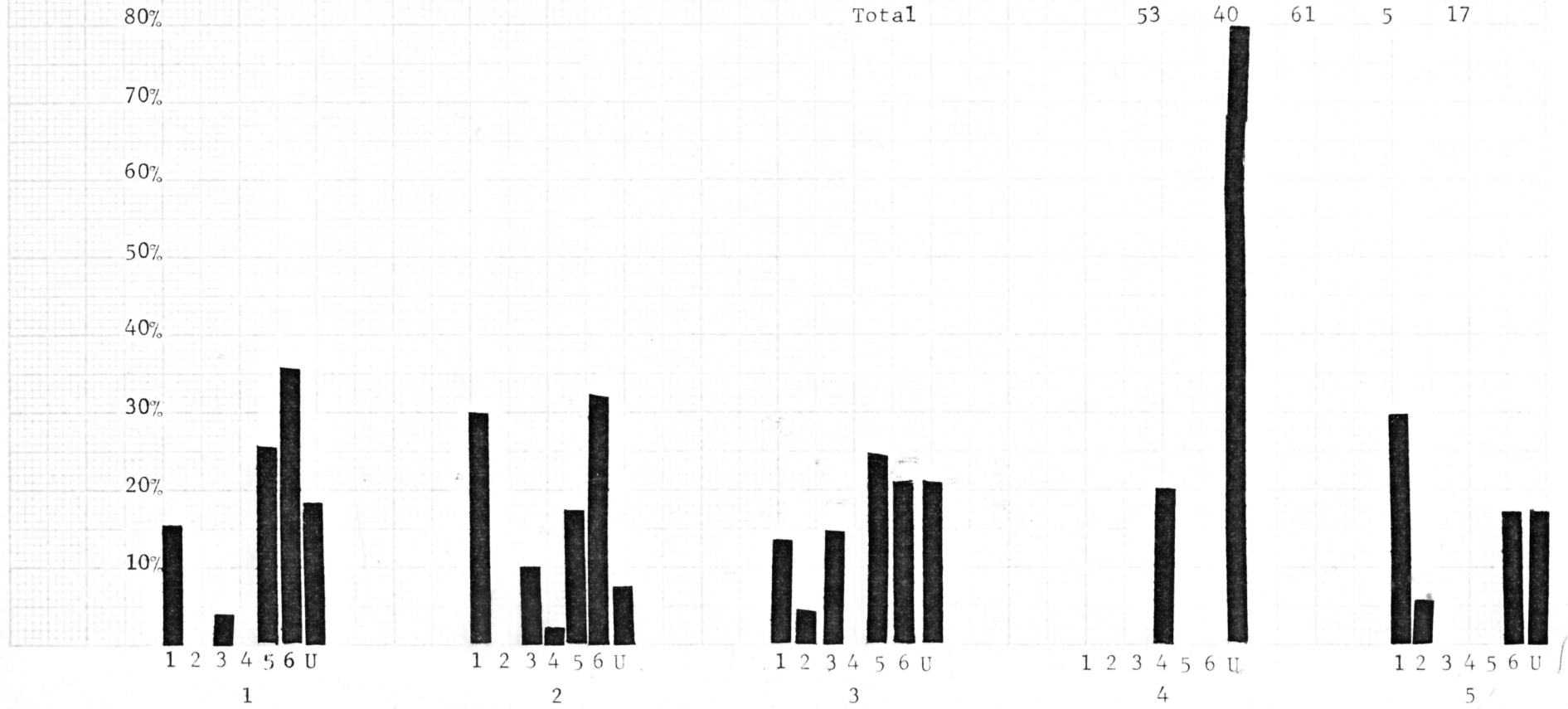
Fairview, lower bed, series 12 Figure 6

Species	number in each sample				
	1	2	3	4	5
1. Drepanodus suberectus	4	13		12	29
2. Plectodina furcata	28	31	28	39	24
3. Ozarkodina tenuis		16	6		9
4. Ozarkodina obliqua	2			4	
5. Ozarkodina polita			4		
6. Bellodina compressa		1			
7. Oulodus oregonia	5	4		3	3
8. Phragmodus undatus			1	1	
9. Distacodus falcatus					2
U. Unidentified	10	9	14	23	26
Total	49	86	53	82	93



Fairview, upper bed, series 14 Figure 7

Species	number in each sample				
	1	2	3	4	5
1. Drepanodus suberectus	8	12	8		5
2. Oulodus oregonia			3		1
3. Ozarkodina tenuis	2	4	9		3
4. Panderodus gracilis		1		1	
5. Phragmodus undatus	14	7	15		
6. Plectodina furcata	19	13	13		4
U. Unidentified	10	3	13	4	4
Total	53	40	61	5	17



Fairview 2 Section

The section referred to as Fairview 2 Section is a road cut on the east side of U.S. Route 68 in Mason County, Kentucky about 100 yards from the Fleming County line (Fig. 4). The rocks exposed in this section consist of predominantly limestone similar to that of the Fairview Formation in previously described exposures. Furthermore, the important index fossil Oulodus oregonia velicuspis, which appears in uppermost Kope strata and ranges into the Fairview Formation (Sweet and Bergstrom 1971), is present in the samples from this section. Accordingly, the rocks exposed in this section are classified as the Fairview Formation.

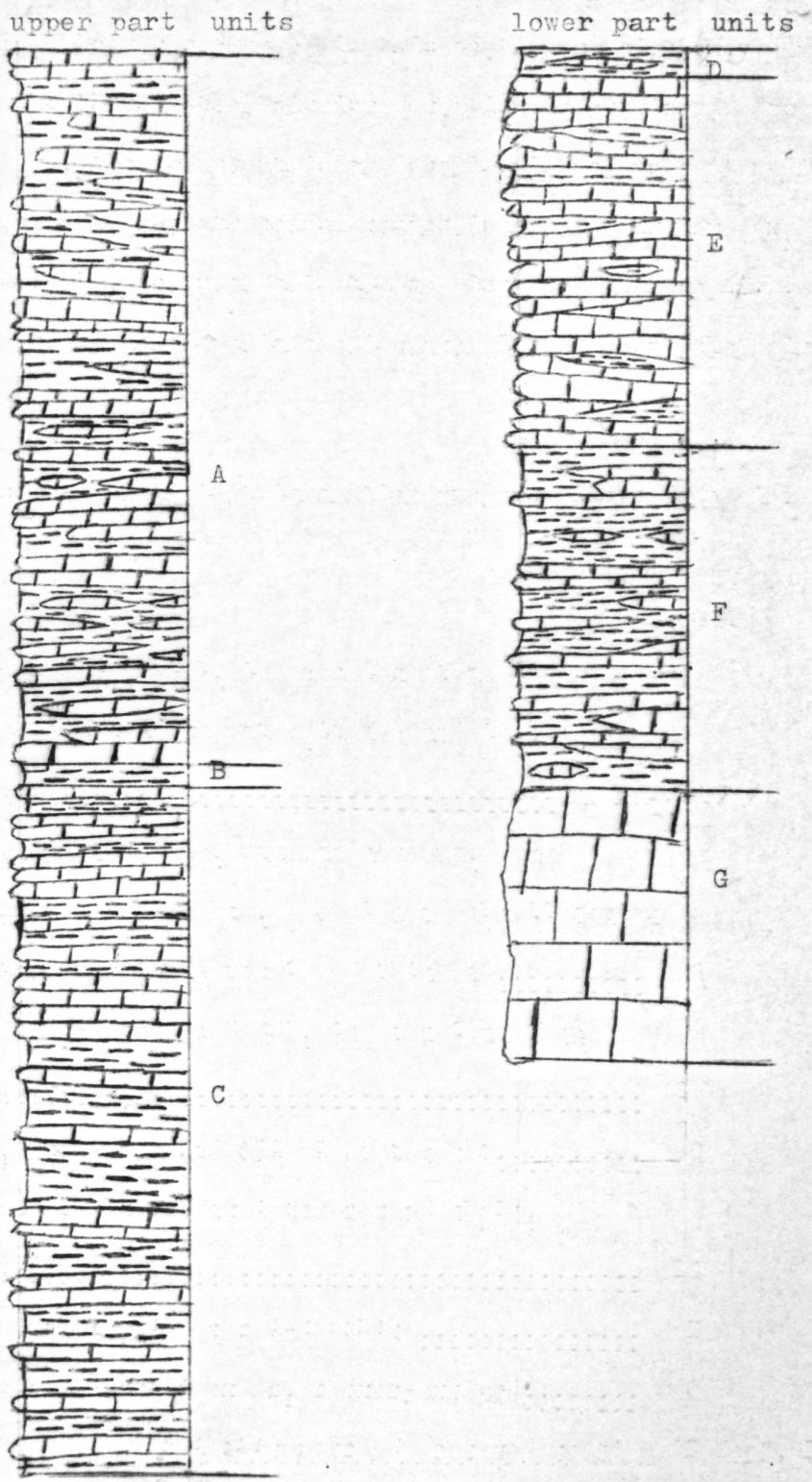
The lithologic units recognized in this section are as follows (see Fig. 8 for columnar section):

	feet	inches
Unit A. Limestone (predominantly), in beds less than 4" thick. This is the uppermost unit exposed in the cut.....approx.	20	0
Unit B. Shale, gray, fine-grained, very calcareous, very prominent and persistent bed. Samples of the 12 series were collected from the lower 2" of this bed.....	0	4
Unit C. Shale (40%) and limestone (60%), in beds less than 4" thick.....	19	0
Unit D. Shale, gray, prominent bed all along the cut.....	0	7
Unit E. Limestone, gray, with a few interbeds of shale, 1-3" thick.....	10	3
Unit F. Limestone and shale, in beds 1-5" thick.....	7	8
Unit G. Limestone, gray, fossiliferous, coarse-grained.....	6	0
Total thickness of measured section	63 feet, 10 inches	

Figure 8

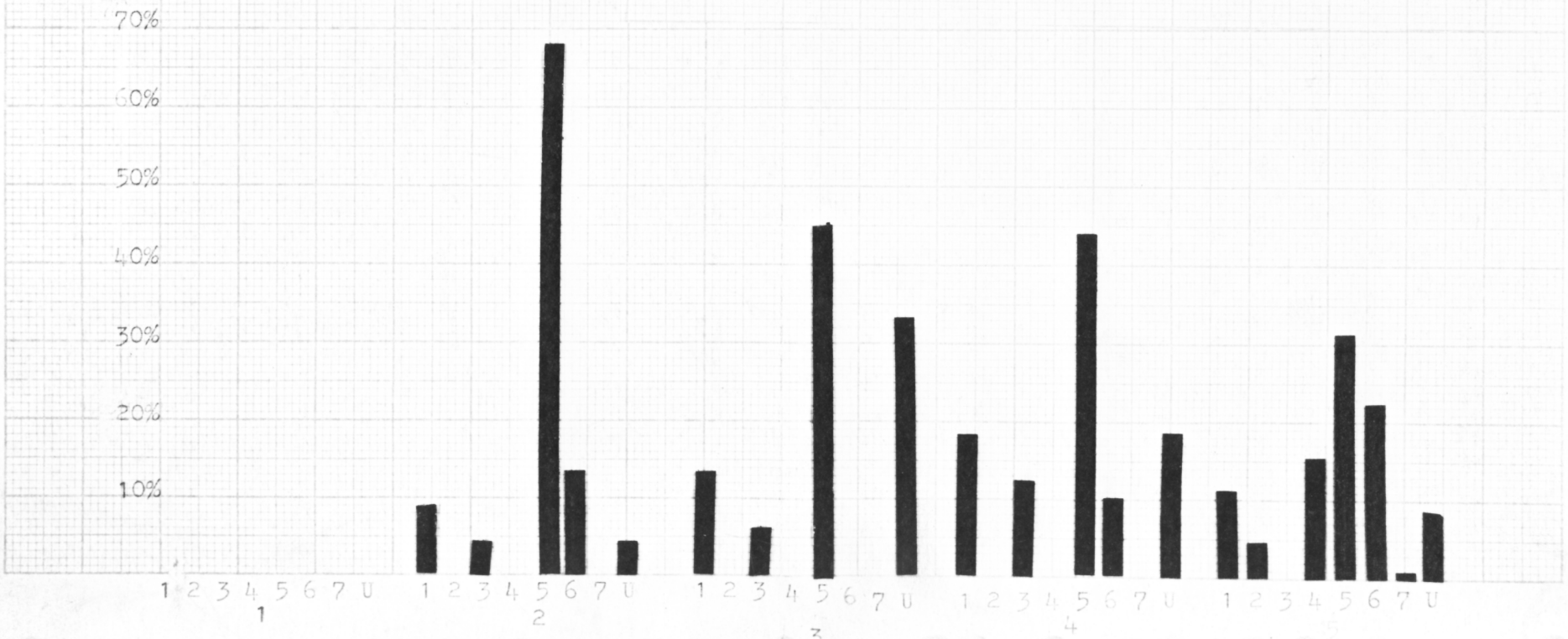
Scale: 1:50

Fairview 2



Fairview 2 Figure 9

Species	number in each sample				
	1	2	3	4	5
1. Drepanodus suberectus		2	2	3	10
2. Oulodus oregonia					4
3. Ozarkodina obliqua		1	1	2	
4. Ozarkodina polita					14
5. Phragmodus undatus		15	7	7	28
6. Plectodina furcata		3		1	20
7. Oulodus oregonia velicuspis					1
U. Unidentified		1	5	3	8
Total	0	22	15	16	90



The samples of series 12 were taken from Unit B. Sample 12-1 was collected from the northern end of the exposure and the other samples from the same bed going southward. The distance between successive samples is as follows:

From 12-1 to 12-2 ..... 84 feet
12-2 to 12-3 ..... 72 feet
12-3 to 12-4 ..... 48 feet
12-4 to 12-5 ..... 60 feet

A list of conodont species found in these samples and the relative frequency of these species are given in Fig. 9.

Perry Lane Section

The section here referred to as the Perry Lane Section is a road cut on the east side of U.S. Route 68 in Mason County, Kentucky, just north of Perry Lane (Fig. 10). The rocks exposed in this section are of a lithology similar to that of the Fairview Formation elsewhere. Furthermore, the samples collected have yielded the guide fossil Oulodus oregonia velicuspis. The rocks in the cut are therefore classified as belonging to the Fairview Formation.

The lithologic units recognized in this section are as follows (see Fig. 11 for columnar section):

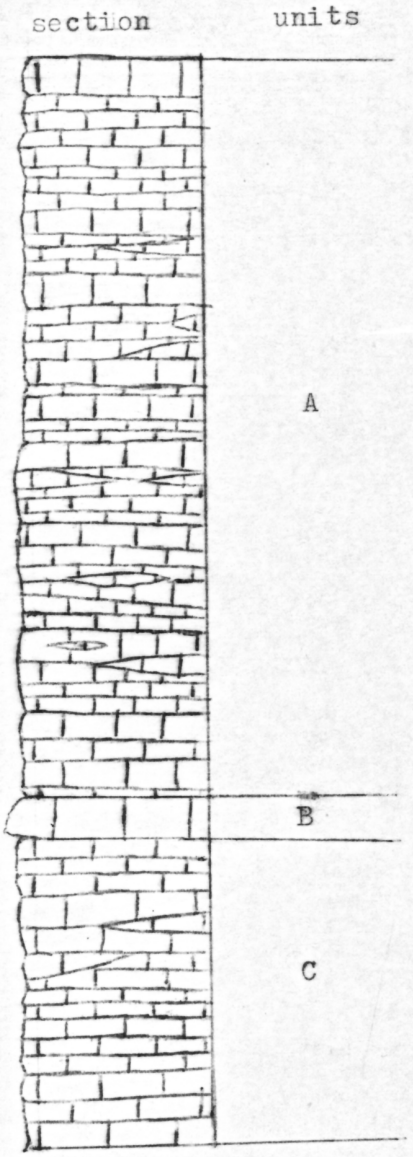
	feet	inches
Unit A. Limestone, gray, fossiliferous, in beds 2-5" thick. This is the uppermost unit in the exposure.....	12	0
Unit B. Limestone, gray, fossiliferous, one prominent bed. Samples of the 13 series were collected from this bed...	0	7
Unit C. Limestone, similar to that of Unit A.....	4	10
Total thickness of measured section	17 feet, 5 inches	

The samples of the 13 series were collected from Unit B. Sample 13-1 was taken 216 feet north of the south end of the cut. The other samples were taken at the

Figure 10 from Mays Lick Kentucky 7.5 minute topographic quadrangle 1952 scale 1:24,000 Location of section indicated by circle.

Figure 11
Scale: 1:30

Perry Lane

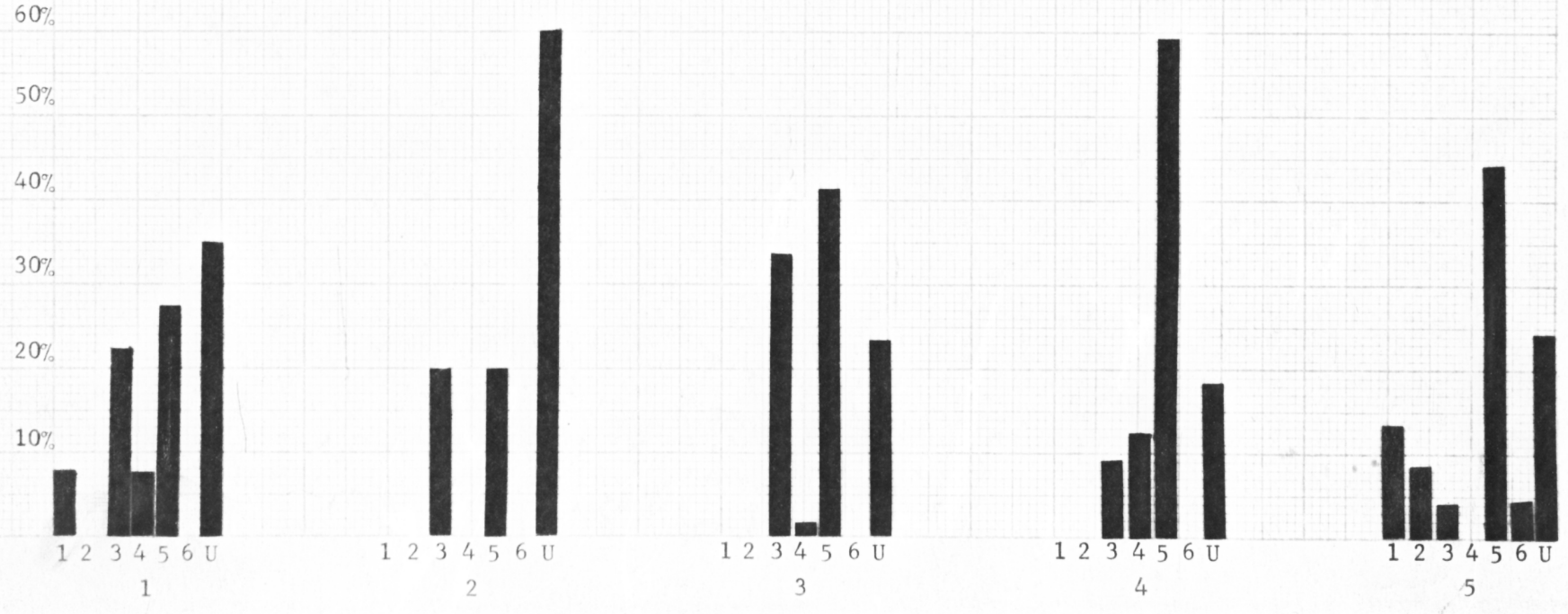


Fairview

Formation

Perry Lane Figure 12

	Species	number in each sample				
		1	2	3	4	5
1.	Drepanodus suberectus	3				6
2.	Oulodus oregonia					4
3.	Ozarkodina tenuis	9	1	19	3	2
4.	Phragmodus undatus	3		1	4	
5.	Plectodina furcata	11	1	23	19	20
6.	Oulodus oregonia velicuspis					2
U.	Unidentified	14	3	13	6	11
	Total	40	5	56	32	45



following intervals going southward from this point:

From 13-1 to 13-2 ..... 54 feet

13-2 to 13-3 ..... 36 feet

13-3 to 13-4 ..... 54 feet

13-4 to 13-5 ..... 84 feet

A list of conodont species found in these samples and the relative frequency of these species are given in Fig. 12.

Discussion

As indicated by Figs. 3, 6, 7, 9, and 12, the relative frequency of representatives of individual conodont species in each of the samples investigated shows considerable variation. Accordingly, it is obvious that in the sections studied, the frequency of conodont elements of a particular species in very thin stratigraphic intervals shows variations laterally. Some of the species show a variation of only a few percentage points in the different samples from the same bed but these are all species which are not present in some samples and, as a whole, make up only a small percentage of the total number of conodont elements in other samples. In other words, as might be expected, the more rare elements show the smallest variation in relative frequency.

Among those conodont species represented in every sample collected from a particular bed, the least relative frequency variation is exhibited by Plectodina furcata in sample series 11, which is from the lowermost collected bed in the Fairview Section. In this bed, representatives of the species mentioned make up between 26 percent and 57 percent of the total number of elements in the samples for a total variation of 31 percentage points.

By and large, there is a strong similarity between each of the samples from a particular bed in that certain species tend to be abundantly represented whereas

others are represented by relatively scarce specimens. However, this general similarity is not very significant in terms of the whole collection at hand and it does not appear possible to recognize samples of a particular bed solely on the basis of its species frequency spectrum.

Of interest in this connection is also whether or not lithologic differences are related to differences in the relative abundance of representatives of a particular species. The samples collected from the Fairview 2 Section are very calcareous shales whereas the other samples consist of different types of limestones. The Fairview 2 samples show a very wide variation in the absolute number of conodont elements from sample to sample; this number ranges from 0 to 90. However, in those four samples of this bed in which conodont elements were found, the variation in the relative abundance of the various elements is not greatly different compared to the variation in samples from other beds. The upper bed of the Fairview Section from which samples of the 14 Series were collected is a very argillaceous limestone. The absolute number of conodont elements in samples of this bed shows a variation from 5 to 53, a figure which is very similar to those of the relatively pure limestone samples of the Blue Licks State Park and Perry Lane sections; in both of these, the number of elements varies from 5 to 56 in the same bed. Accordingly, it would appear as if the variation in the total number of elements in a particular bed is not closely related to the lithology of the bed; one would otherwise have expected that coarse-crystalline, richly fossiliferous limestones with fossils showing indications of having been transported, would exhibit greater variation in the number of conodont elements than shaly beds showing no obvious evidence of strong water currents in the environment of deposition. In general, the abundance of conodont elements varies randomly and does not constantly decrease or increase in a particular direction in the sections investigated. An exception to this is the Blue Licks State Park Section, in which the conodonts are more numerous in samples

from the central part of the section. There seems to be no clear relations between the similarity in abundance of conodont elements and the lateral distance between samples.

In conclusion, the present study suggests that in the area studied, the relative frequency of elements of individual conodont species varies widely horizontally in samples collected from the same thin stratigraphic interval. This variation seems to be independent of facies, distance between samples, and applies to all conodont species found in the samples studied. There is also a considerable variation in the total number of specimens found in samples of the same bed and also this variation appear to be unrelated to differences in lithology and distances between the individual samples. The factor(s) causing these frequency variations is not determined at the present time but apparently, it is not simple a postmortem transportation process. The considerable variation in the relative abundance of individual types of conodont elements in the same thin stratigraphic interval was unexpected and calls for further investigations. Correlations using "relative abundance analysis" have been based primarily on Phragmodus undatus, a species which is, unfortunately, not abundantly represented in the samples studied. It is therefore still uncertain if, also, this species, in general, exhibits the same striking local lateral frequency variations as the other species in the samples investigated. In other words, the present study has not been extensive enough to fully evaluate the validity of the basic assumption behind the use of "relative abundance analysis" as a aid for correlation and additional, more extensive studies using statistical techniques are clearly needed.

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